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EMBEDDED OUTLINE FONT LIBRARY BASED ON DESCRIPTION OF
STROKE CENTERLINES

5 **Field of the Invention**

This invention relates to data processing, especially to the data structure font library that could change the data to be processed into the data that the computer could process, this invention would be used in the Chinese character information processing by computer.

10 **Background of the Invention**

The font library is the important one of the OS. Seeing as the number of the Chinese characters is big, the font library is the base of the processing of Chinese information on OS. Using the font library, the Chinese characters could be displayed and imported.

15 There are three conventional font library technologies including bitmap font, vector font and outline font.

The advantages of bitmap font are that making and displaying of the bitmap font is easily, but it also has its disadvantages, it couldn't be magnified or reduced. Besides when it was magnified the font capability would be square increased. If the 20 bitmap font has several sizes, its capability is very huge. So that the bitmap fonts were used on the early OS or the embedded equipment having lower requests on the characters display.

The vector font library and the outline font library are popular on the OS at present, there are two types mostly, TrueType and Postscript. Now the most of PC 25 Os use these two font libraries. The advantages are that these font technologies are mature, the font style is nice and it could be magnified and reduced. The disadvantages are that the structure of the font library is complex, the font revivification generator is complex, the effect of the small characters display is bad, the revivification speed of characters is slow, the capability of the font library is big

and it could not meet the need of the embedded system. The font library technologies were both invented by America. We not only should pay much money, but also the development of our Chinese information processing would be baffled, it is abnormal that we are restricted on the Chinese characters font library technology
5 area.

Summary of the Invention

First of all, in the market there are no outline fonts that could meet the need of the embedded system, because the capability of the embedded system is small. It will increase the cost while increase the memory capability. One typeface GB18030
10 of TrueType font takes 20Mbyte storage space, and four typefaces take 80Mbyte in total. At the present the advanced embedded system usually has only 16Mbyte memory. The system itself cost some, the left is small and could not hold the huge outline Chinese font library. Many advanced PDAs and cell-phones could not be put in China market because they haven't been Chinese localized. As a result, they
15 haven't found the way to meet the needs of the Chinese embedded system. So it is necessary to invent a new kind of font library technology, which has nice fonts at every size, the character could be magnified and reduced without restricted, the structure of the font library is legible, the font generator is used easily and the display speed is quick. Besides the font library capability is small so that it could
20 meet the need of the embedded system.

Furthermore, we have to invent a new font that is defined by our own country. This new font library technology should have self-property font style generator, it could be the country standard and it could be the technology barrier when the foreign company put embedded products in my market. So then it could protect our
25 embedded Chinese information area keeping the top station.

The invention is firstly realized on the Windows OS by using C language, then on the embedded OS UNLEUS and is solidified on the memory (testing). At last we all hope that it could be made into font library chip and font library explainer chip and solidified into the embedded CPU.

This font library is named as “Font library products based on the description of stroke centerlines”. It will be called “Embedded ZGX outline font library” for convenience, i.e. the part “based on the description of stroke centerline” is replaced by “ZGX”.

- 5 1. A font library based on the stroke centerlines, every stroke is divided into several segments according to its shape: head, body, corner and tail. There are several bodies and corners in one stroke, the segments are described in lines or Bezier curves. The key points of the segment are the control points of the segments. The relative locations of segments based on the control points describe
10 the coordinates of the outline curve. The length of the stroke data is not equal to each other. The tail of the stroke ends the stroke.

The data format of the stroke library is that: the total amount of stroke takes two bytes;

- 15 The structure of the head of the stroke library is that: the length of the data is equal to the byte number of the total stroke number multiplying 4. Every stroke holds 4 bytes, the first 3 bytes are the location index of the stroke, the last 4 bits of the last byte describes the curvature change and the front 4 bits describes the number of the segment that could be curve changed.

- 20 The data of the stroke: the data of the stroke centerline and the outline curve data.

Different font style have different stroke library, usually there are 1000 strokes in the stroke library, the data length of the strokes from 20 bytes to 100 bytes.

- 25 2. A font library directly composed by strokes, the structure of data is:
 the relative location of the stroke data holds 4 bytes;
 the amount of all characters: 4 bytes;
 the index of characters: the length of data is equal to the byte number of character number multiplying 4, and every character holds 4 bytes, the first byte describe the number of its strokes which make up of the character, the next 3 bytes describe the character location.

- 30 The parameter data: the length is equal to the number of 8 multiplying the

strokes that make up of the characters, every stroke parameter holds 8 bytes, they are the number of the stroke (2bytes), the thickness (1byte), location (2bytes), scaling coefficient (12bits) and curvature change increment (12bits);

the stroke library: as we have mentioned above in 1.

5 3. A component library composed by strokes, the data format is that:

The maximum amount of strokes contained in each component: takes 4 bytes, and usually ranges from 20 to 29, namely the maximum amount of the strokes contained in a component is from 20 to 29. The components are ordered by 1-stroke components, 2-stroke components, till 20~29-stroke components.

10 The index table of N-stroke components: holds $4 \times N$ bytes (suppose N is the maximum number of the strokes which make up of the components). Every location number of strokes components holds 4 bytes, that is: the location index of 2-stroke component, the location index of 3-stroke component and till to the location index of n-stroke component, the components which are made up by same amounts of
15 strokes have some, from the number 1 to the maximum number, the components which are made up by 2-stroke hold 2×8 bytes, the components which are made up by 3-stroke hold 3×8 bytes, and so on.

The parameter data: 8 multiplying the number of the bytes which make up the component, every stroke parameter data hold 8 bytes, that is: the stroke number which holds 2 bytes, the thickness coefficient which hold 1 byte, the stroke location which holds 2 bytes, the stroke scaling coefficient which holds 12 bits and the stroke curvature change increment which holds 12 bits.

4. A font library composed by components, its data format is that:

version information: 4 bytes, the first 2 bytes is the name of corporation, the third byte is the symbol of the font style and the last byte is the symbol of the characters sets.

The start location of the character parameter: 4 bytes;

The start location of the component parameter: 4 bytes;

The start location of the stroke parameter: 4 bytes;

30 The character index data table: (total amount of characters+1)*4 bytes, the first

4 bytes is the total number, the next $4*n$ bytes is the index of every characters, the first 3 bytes is the character location, the last 1 byte is the component number which make up of the character.

The character parameter data is that: the component number make up of the character holds 6 bytes, they are that: the component number which holds 11 bits, the strokes number make up of the component holds 5 bits, the component location holds 2 bytes, the component scaling coefficient holds 12 bits and the thickness coefficient holds 6 bits;

The component parameter data: see 3;

The stroke library: see 1.

5. A font library of multi-font data-shared format, various font style libraries have the same component number and the same stroke number, and this part is described in one basic font, and is shared by other font library; its data structure is that:

15 The data format of basic font has been described in 4;

The other font data format is described as following:

The start location of the character parameter: 4 bytes;

The start location of the component parameter: 4 bytes;

The start location of the component parameter: 4 bytes;

20 The character index data table: $4*(n+1)$ bytes (n is the total amount of characters), the first 4 bytes denote the index of each character, later each 4 bytes denote the index of every character, where the front 3 bytes in every 4 bytes denote the character location, the last 1 byte denotes the amount of components contained in the character.

25 The character parameter data is that: the component number make up of the character holds 4 bytes, respectively the component location holding 2 bytes, the component scaling coefficient holding 12 bits and the thickness coefficient holding 4 bits;

30 The component parameter data: see 3, but without the stroke number; the stroke parameter data: see 1.

6. An explainer of strokes for ZGX font libraries (program module).
7. An explainer of stroke-composed characters for ZGX font libraries (interface application program module).
8. An explainer of components for ZGX font libraries (program module).
- 5 9. An explainer of component-composed characters for ZGX font libraries (interface application program module).
10. An explainer of multi-font data-shared characters for ZGX font libraries (interface application program module).

The advantages of this technology include: low memory cost while keeping the elegance appearance of characters. Usually, one-font standard GB18030 (includes 27590 Chinese characters and 1136 other characters, 28736 in all) will cost 1.1M bytes. Here Standard means every font has its own data file, has specialized parameters, components and strokes. This technology will only need one shared font-lib that takes 800k bytes. Various fonts could share the same data somehow, Song will take 800k, Fangsong, black and Kai only take 600k each and thus in all 2600k (2.6M). TTF will take more than 100M if 7 fonts are needed, in compare, only 4.5M will needed.

This technology is optimized, it could provide in focus characters. It only takes very few memories. It only takes 40k bytes for codes and thus enjoys a high speed. 20 It uses standard C language to program. The Core module uses integers and could be links to various OS. It could change size automatically and add a function to amend the thickness of the strokes that could not be available so far. That would be a crucial advantage for those embedded systems. So it has wide usage.

Brief Description of the Drawings

- 25 Fig.1 is a flow chart of main module;
- Fig.2 is a flow chart of reading in font lib data files;
- Fig.3 shows a process of Changing from Standard code/UNICODE to ZGX;
- Fig.4 is a flow chart of drawing strokes according to ZGX characters' numbers;
- Fig.5 is a flow chart of Stroke generator;

- Fig.6 shows a flow chart of Bezier lines generator module;
- Fig.7 is a flow chart of generating a stroke by one or more Bezier line(s);
- Fig.8 is a flow chart of generating a stroke by one or more Beeline(s);
- Fig.9 is a flow chart of Beeline transfer sub-module;
- 5 Fig.10 is a flow chart of Beeline sub-module;
- Fig.11 is Sub-module of drawing bitmaps in buffer;
- Fig.12 is a flow chart of Fill-in sub-module;
- Fig.13 is a flow chart of E table sub-module;
- Fig.14 is a flow chart of CXBOTOOM sort ascending sub module;
- 10 Fig.15 shows file data format of parameterized strokes;
- Fig.16 shows data format of parameterized strokes;
- Fig.17 shows control word format of stroke centerline;
- Fig.18 shows control word format of stroke outline;
- Fig.19 shows file data format of components data;
- 15 Fig.20 shows data format of data file of stroke-composed characters;
- Fig.21 shows data format of stroke structure parameters;
- Fig.22 shows component-composed characters index;
- Fig.23 shows character parameters data format of Component-composed characters;
- 20 Fig.24 shows component parameters data format of component-composed characters;
- Fig.25 shows stroke parameters data format of component-composed characters;
- 25 Fig.26 shows character parameters data format of part shared component-composed characters;
- Fig.27 shows component parameters data format of part shared component-composed characters;
- Fig.28 shows stroke parameters data format of part shared component-composed characters;
- 30 Fig.29 shows a compute screen coordinate system;

Fig.30 shows a character coordinate system;

Fig.31 shows a character component coordinate system;

Fig.32 shows a stroke coordinate system.

Detail Description of the Preferred Embodiments

5 To illustrate the implementing process as showed in Fig. 1-32:

1. Summary

This technology is used for character information processing. It defines a particular curved outlines font lib data structure. This data structure includes 10 strokes and components data and thus the best characters are generated with generator. It is characterized in that: the lowest memory cost while keeping its elegance. Usually, one-font standard GB18030 (includes 27590 Chinese characters and 1136 other characters, 28726 in all) will cost 1.1M bytes. Here Standard means every font has its own data file, has specialized parameters, 15 components and strokes. This technology will only need one shared font-lib that takes 800k bytes. Various fonts could share the same data somehow, Song will take 800k, Fangsong, black and Kai only take 600k each and thus in all 2600k (2.6M). TTF will take more than 100M if 7 fonts are needed, in compare, only 4.5M will needed. That would be a crucial technology for embedded system, which has 20 limited memory resources. So it has wide usage.

Terms used by ZGX are defined as following:

1.1. Strokes of ZGX font libraries

ZGX font lib strokes are the basic elements to form characters. Different 25 strokes are represented by different stroke index. The strokes can be classified as Heng, Shu, Pie, Na, Dian that could be further divided to over 30 groups. In ZGX, over 1000 strokes shall be made. Strokes include centerlines, constructions and outlines. The outlines will form a closed curve.

The centerlines are skeletons of the character. It includes control dots for all

strokes and consists of beelines and Bezier lines.

Strokes include head, body, inflexion and tail. Every part has control dots as reference to describe its outlines. Outlines consist of beelines and Bezier lines.

The stroke segments index indicates its formal index, from 0 to max.

5 The stroke curvature indicates that in the head or tail, some control dots' positions are changed. It has 15 modes from mode 1 to mode 15.

The curvature change segment number and the curvature change mode will be given in the index file of stroke library.

10 1.2. ZGX font lib components

ZGX font lib components are formed with some strokes. It could be classified as 1-stroke component, 2-stroke component, 3-stroke component...and the maximum is 31-stroke component. The components are represented by the amount of strokes of component (how many strokes the component has) and their own index number, and such data could be shared around variety-font products.

15 The strokes forming components have parameters of strokes number, thickness coefficient of stroke, center coordinates of stroke in x direction and y direction under component coordinate system, scaling coefficients of stroke in x direction and y direction and curvature diversification of stroke in x direction and y direction.

20 The stroke number could be shared in various font lib products as common data.

Coordinates for stroke center under component coordinate system are limited from -128 to 127. It is defined when customizing font lib products, and represented 25 in one byte.

The thickness coefficient works on outlines of strokes, it will make strokes thick or thin. It could make effect on special section and decorates the fonts.

Scaling coefficient in x direction and y direction will only work on control points within centerlines. It will not change the thickness so that the consistency in the 30 thickness of the stroke will be ensured. Scaling coefficient is defined when

customizing font lib products, takes a value from 0 to 255 and be saved in one byte also. Wherein 128 denotes double zooming. In compact mode, it could be defined in 6 bits and thus has a limitation from 32-95, the saving format is that the number above described subtracts number 32, that is it is saved as 0 to 63. Whereas 64 5 denotes double zooming in compact mode.

Curvature diversification in x coordinate and y coordinate means changes in head, tail or some common section. It has 15 modes to work on a single section or 10 2 sections. (at most 2 sections.) For examples, x coordinates in head and y coordinates in tail is one mode, and x coordinates in common section and y coordinates in it is another mode. The premier will solve compound stroke (such as 15 hengzhe) problem and the ratio problem of heng section and zhe section, and the latter one solve the problem that the same stroke in different component has different curvature diversification. This parameter will make ZGX fonts precisely same as any font templates, so that the precise and beautifulness of the character in font library will be ensured. Each curvature change increment is between -128 and 127, and is expressed with one byte. In the compact font format, the curvature change increment can be expressed with six bits format, because the curvature change increment is usually small.

20 1.3. Characters of ZGX font library

ZGX font library is expressed with numbers, which can be from 1 to N (N is a long integer), so the amount of the characters is no limited and the font library can be super large. ZGX font library can be ordered according to both Unicode standard and Chinese standard (such as GB2312, GBK and GB18030).

25 The character of ZGX font library can be formed by several components, also several strokes directly. The former is called component-composed character, while the later is called stroke-composed character.

Stroke-composed character means that the character is formed by several 30 strokes, whose parameters data include: the number of each stroke composing the character, the thickness of each stroke, the coordinates of each stroke center in the

character coordinate system, the scaling coefficients of each stroke in X direction and Y direction, and the curvature change increments of each stroke in X direction and Y direction. The explanation of each parameter of stroke-composed character is the same with the description of components of ZGX font library in section 1.2.

- 5 Component-composed character means that the character is formed by several components, whose parameters data include: the amount of strokes of each component (how many strokes the component has), the number of each component, the coordinates of each component center under the character coordinate system, the scaling coefficients of each component in X direction and Y direction, and the thickness coefficient of each component. Components are 10 composed of strokes, as explained in section 1.2.

The amounts of each component's strokes (how many strokes the component has) and the numbers of the components are the data that can be shared in multi-font library products. It is only needed to be in the font file of one typeface.

- 15 The coordinates of each component center under the character coordinate system are decided according to the structure position number. There are 31 kinds of structure position numbers, such as left-right structure, up-down structure, surround structure etc., which are determined when font library product is customized.
- 20 The scaling coefficients of component in X and Y directions are limited between 0 and 255, and each is expressed by one byte. In compact format, 0 to 63 represents 32 to 95 respectively. Each scaling coefficient is expressed by six bits, and the scaling coefficient "64" means double.

25 **1.4. Extern called parameters for generating character**

- When a character is generated in the device coordinate system, the parameters used are font number of the character, Chinese standard code (or Unicode standard) of the character, length of the character (unit: pixel), width of the character (unit: pixel), thickness coefficient of the character, foreground color of the 30 character, display mode of the character (such as rotation, bold, oblique, fill etc.).

and the bitmap data of the character returning from the buffer.

In principle, the extern called parameters has no limit on the length, width and thickness of the character. This means that one kind of typeface can be any length, width and thickness, so the character can be long or short, bold or thin, also one typeface character may be used as many kinds of typefaces.

1.5. Technical specification of ZGX font library

Under the premise of ensuring preciseness and beauty of characters, ZGX characters can save memory and accelerate the display speed mostly.

The standard format GB18030 font library (27590 Chinese characters and 1136 non-Chinese characters, 28726 codes together) of one font is 1.1MByte (while TrueType font library is over 15Mbyte). The compact format GB18030 font library of Songti typeface is 800KByte, and the compact format GB18030 font library of Fangsong, Heiti, Kaiti typeface is respectively 600Kbyte. Compact format GB18030 font library of four typefaces is 2.6MByte together, and font library of seven typefaces is 4.5MByte together.

The revivification algorithm of ZGX font library is more excellent than that of TrueType font library, because the filling process of the former is aimed at each stroke while not the whole character, so the filling speed of ZGX is faster. Additionally, the index of ZGX is simple and direct, and all the math operations are integer operation with overall optimization.

2. Data format of ZGX font library

2.1. Data file of strokes (see Fig. 15)

Data file format of strokes (see Fig. 16).

The data format of control word for each stroke centerline segment is represented in one byte. The definition of every bit of the control word is in Fig.17.

Data of the stroke centerline segments include: head coordinates (2Byte), control word of segment (1Byte), body data (2*z00Byte), and tail control word.

Data of the stroke outline segments include:

Control data format of each segment is represented in 1 Byte, the definition of every bit of the word is explained below (see Fig.18).

Data format of stroke outline segment: segment control word (1 Byte), coordinates increment of 1st edge outline(2 Byte), coordinates increment of 2nd edge outline(2 Byte), other points coordinates of the head ($2 \times tqy$ Byte), body data ($4 \times z00$ Byte, including points on 1st and 2nd edge outlines); corner control word (1Byte), 1st outline coordinates increment (2Byte), 2nd outline coordinates increment (2Byte), other points coordinates of the corner ($2 \times tqy$ Byte), body data ($4 \times z00$ Byte, including coordinates of points on 1st and 2nd outlines); tail control word, other points coordinates of the tail ($2 \times tqy$ Byte).

2.2. Data file of components

Please see Fig.19.

15 **2.3. Data file of Stroke-composed characters**

The first four-byte denotes the start position of stroke data.

The second four-byte denote the amount of Chinese characters.

Then, the index data of every Chinese character takes four bytes orderly, where the first byte is the stroke amount of the character, and the rest three bytes 20 denote the position of the stroke data in the stroke parameter file (see Fig.20).

The length of this data block is $4 * \text{amount of characters}$.

The following data block is the stroke structure parameters: every stroke takes 25 8 bytes, where the first two bytes denote the stroke number, the third byte denotes the thickness of stroke, the later five bytes are the X, Y, SX, SY, QX, QY of the stroke (see Fig.21).

The storage of the data block is: amount of all Chinese characters' strokes*8 bytes;

Next is the stroke generating data block. It is composed of:

The amount of strokes: 2 bytes;

30 The index of stroke data: $4 * \text{amount of strokes}$, stroke data (Fig.15 is the

compact format of stroke data file).

2.4. Data file of Component-composed characters

Basic font file is mainly composed of several parts: index table, character parameter data, component parameter data and stroke data.

5 Index table (see Fig.22)

Character parameter data (see Fig.23)

Component parameter data (see Fig.24)

Stroke data (see Fig.25)

10

2.5. Format of part shared multi-font component-composed characters

Other font files are mainly composed of index table, character parameter data, component parameter data, and stroke data. The data formats in detail are described as following:

15 Index table (see Fig.22)

Character parameter data (see Fig.26)

Component parameter data (see Fig.27)

Stroke data (see Fig.28)

20 **3. The mathematical model and its font generator device**

3.1. Coordinate system

ZGX font library uses following coordinate systems: device coordinate system (relative to printer or other devices), character coordinate system, component coordinate system and stroke coordinate system.

(1) Device coordinate system

Take computer's monitor as an example, the definition of the screen is as Fig.29.

The origin of the screen is (0,0) at the top left corner. The Y-axis is down, and the X-axis is rightward. The resolution of VGA is 640*480, so the coordinates of the bottom right corner is (639,479).

(2) Character coordinate system

In Fig.30, $x_1o_1y_1$ is the coordinate system, and xoy is the device coordinate system. The center of the character is in the device coordinate system.

To display a character, the following data are needed: the number of the character, the scaling coefficients in X direction and Y direction (the resolution of the reference character is 256*256) and the coordinates of the character's center $o_1(x_0, y_0)$ (this point is the origin o_1 of the character coordinate system's center).

Then the character can be displayed right in the given position.

(3) Component coordinate system

In Fig. 31, $x_2o_2y_2$ is the component coordinate system, relative to character coordinate system. And o_2 is the center of a component. Every component has a component coordinate system relative to character coordinate system. Displaying a character is realized by displaying several components. To display a character, it is needed to read the number of each component, the scaling coefficients in X and Y directions, and the relative coordinates (x_{10}, y_{10}) of o_2 .

(4) Stroke coordinate system

In Fig.32, $x_3o_3y_3$ is the stroke coordinate system, relative to component coordinate system $x_2o_2y_2$. Generating a component is realized by displaying several strokes. To generate a component, it is needed to read number of each stroke, the scaling coefficients in X and Y directions, and the relative coordinates (x_{20}, y_{20}) of o_3 in $x_2o_2y_2$ coordinate system. Also, every stroke has a stroke coordinate system.

How to generate a stroke? In the stroke coordinate system, the stroke is gained by filling algorithm according to the stroke's coordinates and curve fitting parameters (read from stroke file according to the number of the stroke).

(5) Fitting of second-order Bezier curve

As shown in Fig.32, the short Pie is divided into three segments, and every segment uses a fitting of second-order Bezier curve.

The first segment uses the coordinates of ①, ②, and ③. The ② is the point of intersection of the tangents of ① and ③.

The second segment uses the coordinates of ③, ④, and ⑤. The ④ is the point of intersection of the tangents of ③ and ⑤.

The third segment uses the coordinates of ⑤, ⑥, and ①. The ⑥ is the point of intersection of the tangents of ⑤ and ①.

5 If curve from ① to ③ is a line, than ② can be any point on the line.

The formula is as following:

$$\begin{cases} x(t) = x_1(1-t^2) + 2t(1-t)x_2 + t^2x_3 & \dots \text{(1)} \\ y(t) = y_1(1-t^2) + 2t(1-t)y_2 + t^2y_3 & \dots \text{(2)} \end{cases} \quad \text{wherein, } t \in [0,1]$$

In the formula, (x_1, y_1) , (x_2, y_2) and (x_3, y_3) are respective the coordinates of the head point, the middle point and the end point.

10 Thus, it is only needed to save the relative coordinates of ① to ⑥ points for Bezier curve fitting. The data format is the same as that of broken line, but the difference is the record of coordinates of even points. And the point is the intersection of the tangents of ore-and-aft two points. During filling calculation, various of methods are adopted.

15 (6) Coordinates transform of generating a character in device

The transform formulas for coordinate points on every stroke of every component from character coordinate system to device coordinate system are:

$$X_{kij} = ((X_{2i} + S_{xBi} \times X_{3j} \div 128) \times B_{xk} \div 128 + X_{k1}) \times Z_{xs} \div 128 + X_0$$

$$Y_{kij} = ((Y_{2i} + S_{yBi} \times Y_{3j} \div 128) \times B_{yk} \div 128 + Y_{k1}) \times Z_{ys} \div 128 + Y_0$$

20 Where,

(X_{kij}, Y_{kij}) denotes coordinates of the i^{th} stroke in the character coordinate system;

(Z_{xs}, Z_{ys}) denotes scaling coefficients of the character;

(X_0, Y_0) denotes character's coordinates in the screen coordinate system;

25 (X_{3j}, Y_{3j}) denotes the i^{th} stroke's coordinates in the stroke coordinate system;

(X_{k1}, Y_{k1}) denotes coordinates of the k^{th} component's center in the character coordinate system;

(B_{xk}, B_{yk}) denotes scaling coefficients of the k^{th} component's center in X and

30 Y directions;

(X_{2i}, Y_{2i}) denotes coordinates of the k^{th} component's i^{th} stroke's center in the character coordinate system;

(S_{xBi}, S_{yBi}) denotes scaling coefficients of the k^{th} component's i^{th} stroke in X and Y directions;

5 $k=1$ ----- the amount of components of the character;

$i=1$ ----- the amount of strokes of the k^{th} component;

$j=1$ ----- the amount of points of the k^{th} component's i^{th} stroke;

3.2. ZGX font generator device

10 The program flow charts are shown as following:

 (1) The flow chart of main module is shown in Fig.1.

 (2) The process of reading font library data into memory array is shown in Fig.2.

15 (3) The process of transforming Chinese Standard code (or Unicode code) into character number of ZGX font library is shown in Fig.3.

 (4) The process of generating Stroke-composed character according to the character number of ZGX font library is shown in Fig.4.

 (5) The process of generating Component-composed character according to the character number of ZGX font library is shown in Fig.1.

20 (6) The flow chart of stroke generator is shown in Fig.5.

 (7) Recursive call module of Bezier curve is shown in Fig.6.

 (8) The sub-module of generating a stroke segment with one Bezier curve or more is shown in Fig.7.

25 (9) The sub-module of generating a stroke segment with one line or more is shown in Fig.8.

 (10) The sub-module of transforming line is shown in Fig.9.

 (11) The sub-module of drawing line is shown in Fig.10.

 (12) The sub-module of drawing bitmap in buffer is shown in Fig.11.

 (13) The sub-module of filling algorithm is shown in Fig.12.

30 (14) The sub-module of edge table (ET) of edges is shown in Fig.13.

(15) Inserting all edges of one item from ET of edges into active edge table (AEL) in ascending order by cxBottom is shown in Fig.14.

4. ZXG font library call interface device

5 4.1. Data structure definition

(1) Return pointer array of font initialization

```
typedef struct fhzz
{
    long * zys;
    long * zics;
    long * zrcs;
    long * bhcs;
}fhzz,far * lpfhzz;

10      zys: data pointer of character index parameter;
zics: data pointer of character parameter for font;
15      zrcs: data pointer of component parameter for font;
zhcs: data pointer of stroke parameter for font.
```

(2) Revivification array of (Chinese) character

```
typedef struct hzfycs
{
    unsigned char zhd;
    unsigned char zkd;
    unsigned char zcd;
    unsigned char zys;
    unsigned char zfs;
}hzfycs,far * lphzfycs;
```

25 zhd: the thickness parameter of Chinese character, 1 Byte, its standard value
is 32;

30 zkd: the width parameter of Chinese character, 1 Byte, using pixel as unit;

zcd: the length parameter of Chinese character, 1 Byte, using pixel as unit;

zys: the color or grayscale of Chinese character, 1 Byte;

zfs: the display mode parameter of Chinese character, 1 Byte.

The definition of parameter value is as following:

The first two bits denote the rotation mode: 00 means the routine (no rotation),

5 01 means 90 degree rotation, 10 means 180 degree rotation, 11 means 270 degree rotation.

The third bit denotes the bold or not: 0 means routine, 1 means bold.

The fourth bit denotes the italic or not: 0 means routine, 1 means italic.

The fifth bit denotes that it is underlined or not: 0 means routine, 1 means

10 underline.

The sixth and seventh bits denote the filling mode of Chinese character: 00 means only drawing centerline i.e. single line character, 01 means filling Chinese character by 'OR' mode, 10 means filling Chinese character by 'AND' mode, 11 means filling Chinese character by 'XOR' mode.

15 The eighth bit denotes the display mode of character: 0 means DBC case, 1 means SBC case, 1 means Chinese character.

4.2. Initialization of font

(1) Interface module

20 HZ_S (zth, lpfhzz) ;

zth: font size, character parameter, these are entrance parameters;

The definitions of parameters are as following:

0: 16*16 bitmap font library according to GB-2312 standard;

1: Outline font library of Songti (Chinese) font according to GB18030-2000

25 standard;

2: Outline font library of Heiti (Chinese) font according to GB18030-2000 standard;

3: Outline font library of Fangsongti (Chinese) font according to GB18030-2000 standard;

30 4: Outline font library of Kaiti (Chinese) font according to GB18030-2000

standard;

5: Outline font library of special characters according to GB18030-2000 standard;

6: ...

5 Lpfhzz: return parameter, pointer of pointer array.

(2) Realization method

Open file according to the size of font, for example, the name of GB2312 16*16 font library file is DW16D, the name of GB18030-2000 Songti outline font library file is DWSTQ, the name of GB2312 Heiti outline font library file is DWHTQ, 10 and the name of special character font library file is DWQZFK.

Twelve memory array are defined respectively as GB2312 16*16 bitmap font array, index parameter array of GB18030-2000 Songti outline font library, character parameter array of Songti font, Songti component parameter array and Songti stroke parameter array; character index parameter array of Heiti outline font library, 15 character parameter array of Heiti font, Heiti component parameter array and Heiti stroke parameter array; parameter arrays of Fangsong, Kaiti, and special character etc.

Read file data according to the font into corresponding array;

Return the pointer of each array.

20

4.3. Revivification of Chinese characters

(1) Interface module

HZ_X(hz\$,zth,hzfycs,fclx,zbuf);

Hzh: size of font;

25 hz\$: the Chinese standard code of a Chinese character, usually 2 bytes;

hzfycs: the revivification parameter array of Chinese character, 5 bytes;

Fclx: the type of a return parameter, 0 denotes bitmap, 1 denotes outline or vector array, 2 denotes TTF data format, 3 denotes PS data format;

30 Zbuf: bitmap of returned Chinese character or other data buffer pointer; this is a returned parameter.

The storage mode of Chinese character bitmap is that every pixel takes 1 bit, every character takes $[(zkd*zcd)+7]/8$ bytes.

(2) Realization method

Find the corresponding array pointer according to the size of font;

5 Calculate the size of Chinese characters according to the inner code. The formula for calculation is as following:

Suppose the higher byte of the inner code is C1, and the lower byte is C2 (C1, C2 are the integer with no sign). If C1=0, then go to DBC case process.

If hz\$ is in the range of character code, i.e. the Chinese standard code is
10 between 0X1F and 0X80, A1A1-A1Fe and A9A1-A9FE, A840-A87E and
A880-A8FE and A940-A97E and A980-A9FE (total amount is 1136), the character
font library DWQZFK will be called. Outline font library uses two steps to generate
Stroke-composed characters. The module of stroke revivification needn't to be
modified. It is only needed to modify the called outline font library file, process the
15 structure file of the character, and calculate the order number ZH of the character in
the font library according to the code:

```
if(hz$>=0x1f && hz$<=0x80) ZH=hz$-0x1f;
else if(c0>=0xa1 && c0<=0xa9 && c1>=0xa1 && c1<=0xfe)
    ZH=99+(c0-0xa1)*94+c1-0xa1;
else if(c0>=0xa8 && c0<=0xa9 && c1>=0x40 && c1<=0xa0)
    {
        ZH=945+(c0-0xa8)*96+c1-0x40;
        if(c1>0x7f) ZH--;
    }
```

25 Else go to the corresponding font file for Chinese font library, and do the following process:

```
If C1>=0XB0 and C1<=0XF7 and C2>=0XA1, then character number
=(C1-176)*94+C2-161;
If C1>=0X81 and C2<=0XA1: if C2>=0X7F, then C2--, character number
30 =(C1-176)*94+C2-64+6768;
```

If $C1 >= 0XAA$ and $C2 <= 0XA1$: if $C2 >= 0X7F$, then $C2--$, character number $= (C1-170)*96+C2-64+12848$;

The number of four-byte character is between 21008 and 27589.

The data describing the character are found according to the character
5 number;

If the character is a 16*16 bitmap font character, then the data pointer of the character is: bitmap font data pointer + (character number - 1) * 32;

If the character is an outline font character, then its character parameter data will be found according to character index file and character number, then the
10 component parameter data will be found according to the character parameter data, and finally the stroke data will be found according to each component parameter data.

The coordinates of each stroke are calculated.

The drawing stroke sub-module is called.

15 The drawing stroke sub-module calls drawing line sub-module and drawing Bezier curve sub-module. In the end, the filling module is called.

Additionally, there are rotation, bold, underline, and italic modules.

(3) Design

An interface module, a drawing stroke sub-module, a drawing line
20 sub-module, a drawing Bezier curve module and a filling sub-module are required by design.

The stroke drawing line sub-module and the filling sub-module need to be realized in buffer.

The calculating of the character drawing control is on the 256*256 rectangle. It
25 is scaled when drawing centerline and outline (firstly, both the length and width of the character are 256; when drawing centerline and outline of the stroke, the following calculating is applied: X coordinate relative to the character's center * character's width / 256, Y coordinate relative to the character's center * character's length / 256).

30 Return the bitmap, vector outline, TTF format or PS format of the character.

Fault tolerance: All characters can be displayed at any resolution without error, distortion and beyond the limits.

4.4. Display of character string

5 (1) Interface module

HZ_C(hzc\$,zth,zxx,zyy,hzfycs);

Hzh: size of font;

hzc\$: the code string of a Chinese character or a set of characters;

Zxx: the X coordinate of the displaying character string in the top left corner;

10 Zyy: the Y coordinate of the displaying character string in the top left corner;

hzfycs: the revivification parameter array of characters, 5 bytes.

15

20

25

30